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A common method of artificially regenerating cottonwood (Populus deltoides Bartr.) is with hardwood cuttings. Sometimes this method has been very satisfactory, and at other times it has failed almost completely. It has been least useful on upland windbreak sites and not entirely successful even on bottomlands (3, 6, 7).[2]

In the research reported here, rooting was studied with respect to the age and size of the cuttings, the value of root-inducing auxins, and the effect of various soil-moisture conditions. Part of the work was done at the Iowa State Forest Nursery and part in the greenhouses of Iowa State College, Ames, Iowa.

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Many of the results reported here have also been published in Allen, R. M., and McComb, A. L. Über Faktoren, die die Bewurzelung der Stecklinge von der Populus deltoides Bartr. beeinflussen. Zentralblatt für das gesamte Forstwesen 74: 199-220. 1955.

2/ Underscored numbers in parentheses refer to Literature Cited, p. 10.

SIZE AND AGE OF CUTTINGS

Methods.--Employing techniques discussed by Doran and others (1, 4), three physical characteristics of cuttings were studied: age of cutting wood, diameter of cutting, and length of cutting. Ages ranged from 1 to 4 years, diameters from 0.3 to 1.3 inches, and lengths from 6 to 18 inches.

The cuttings for the age-of-wood study came from four-year-old wildings growing near Des Moines, Iowa. They were made in January 1948 and stored in moist sand at approximately 40° F. until planted in April.

Because diameter of the cutting, as well as age, might affect rooting, two experiments dealing with age were established. In one, the diameter of the cutting was held constant for all ages, while in the other the diameters (and vigor also) were the average for each age. To obtain cuttings of older wood with the same diameter as cuttings of one-year-old wood for the constant-diameter series, it was necessary to take the cuttings from smaller, less vigorous samplings.

The cuttings for the tests of diameter and length came from one-year-old sprouts on the stumps of 3- to 5-year-old seedlings that had been cut previously. The cuttings were made in December 1947 and stored in moist sand at about 40° F. until planted in April 1948.

The soil was O'Neill sandy loam with good surface and internal drainage. It was loose and well tilled before planting. The cuttings were taken from storage and pushed into the soil until only the distal two inches were above the ground.

These tests were all in the same bed. The arrangement was a randomized complete block design with 10 replicates of 10 cuttings each per treatment. The cutting bed was given no supplementary water during the experiment. The cuttings were lifted and examined four months after planting.

Results and discussion.--Age of cutting was associated with a steady and significant decrease in cutting survival and in the number of roots produced (table 1). The differences associated with cutting age were more pronounced in the constant-diameter series. Since the cuttings in the average-diameter series were larger and presumably of higher vigor, better rooting might have been due to either diameter or vigor. A subsidiary test of cutting diameter using one-year-old stump sprout cuttings of three diameter classes, 0.21 inch, 0.45 inch, and

0.85 inch, gave no significant differences in survival, number of roots, or length of shoot growth. Thus it seems that the better performance of the cuttings in the average-diameter series was due to increased vigor rather than to diameter *per se*.

Long cuttings survived and grew better than short ones (table 2). Since all cuttings had the same length above ground, possibly increasing the length below ground from 4 to 8 to 16 inches brought the cuttings into zones of higher soil moisture. The greater quantity of stored food in the longer cuttings may also have contributed to better root and shoot development. These results agree with recommendations by Maisenhelder (5) that cuttings be set 15 inches deep.

Table 1. --Age of cutting wood, as it affected survival and growth

Age of wood (years)	Cutting diameter	Survival	Roots per rooted cutting	Shoot growth per rooted cutting
	Inches	Percent	Number	Inches
		Constant-diameter series		
1	0.3-0.6	53	25	28
2	.3-0.6	30	20	26
3	.3-0.6	16	15	26
4	.3-0.6	11	12	21
		Average-diameter series		
1	0.3-0.6	53	25	28
2	.5-0.8	39	22	34
3	.6-1.0	30	21	31
4	.6-1.3	18	14	30

Table 2. --Length of cutting, as it affected survival and growth

Cutting length (inches)	Survival	Roots per surviving rooted cutting	Shoot growth per cutting
	Percent	Number	Inches
6	20	14	16
10	42	18	21
18	66	27	29

In summary, survival and root formation were not influenced by cutting diameter, increased significantly as cutting length increased from 6 to 18 inches, and decreased with increasing wood age and decreasing vigor.

CHEMICAL STIMULATION OF CUTTINGS

Methods. --These experiments were made to determine the effects of indoleacetic and indole-n-butyric acid (2) on the rooting of cottonwood cuttings collected in three different seasons. A secondary purpose was to study natural dormancy and to learn whether the time of year at which cuttings were made influenced their ability to root. The latter aim was not accomplished because it was impossible to hold environmental conditions in the greenhouse uniform during the three testing periods. For the same reason, the effects of the chemicals are not comparable for the different seasons.

All of the cuttings in these tests came from one-year-old sprouts growing from the stumps of 3- to 5-year-old saplings that had been cut the previous year. Cuttings were between 0.31 and 0.50 inch in diameter.

Treatment concentrations were 0, 5, 25, 50, and 100 milligrams of indoleacetic acid (IA) or indole-n-butyric acid (IB) per liter of water. The chemical solutions were made by dissolving the IA or IB crystals in ethyl alcohol. From this a stock solution of the highest concentration was made to volume with distilled water. The lower concentrations were made by diluting the stock solution.

Cuttings were treated by immersing their basal two inches in the acid solutions for 24 hours. Immediately after treatment they were placed in a rooting medium consisting of equal proportions of washed sharp sand and neutral peat.

Planting dates were November 25, 1947, December 31, 1947, and March 26, 1948. The November and December cuttings were lifted and measured 65 days after planting, the March cuttings 45 days after planting.

Each test was planted in the greenhouse bench in a randomized complete block design. In each treatment there were 100 cuttings arranged in five replicates of 20 cuttings each.

Table 3.--Influence of growth regulators on cuttings

Date and treatment	Proportion rooted	Proportion surviving	Roots per cutting	Weight of tops
	Percent	Percent	Number	Grams
November				
IA	67	65	4	0.6
IB	79	62	8	.8
Check	36	33	3	.9
Average	61	53	5	.8
December				
IA	31	23	3	1.3
IB	29	19	4	1.0
Check	35	30	3	1.6
Average	32	24	3	1.3
March				
IA	99	37	7	1.9
IB	99	23	5	1.4
Check	92	44	6	1.7
Average	97	35	6	1.7
All months				
IA	66	42	5	1.3
IB	69	35	6	1.1
Check	54	36	4	1.4
Average	63	37	5	1.3

Results and discussion.--The general relationship between auxin treatment and the survival and growth of cuttings is shown in Table 3.

The March cuttings rooted much better than those made in either November or December. The rooting of nearly all the untreated March cuttings suggests that under favorable conditions it is not difficult to root cottonwood.

The differences in rooting and survival may not have

been due to physiological differences within the cuttings. There was little environmental control in the greenhouse, and in April and May, when the March cuttings were rooting, temperatures were 20° F. higher than the 55 to 60° F. daytime temperatures prevalent in January and February. There was considerable mortality among the March and December cuttings. A fungus (Cytospora sp.), which may have followed winter injury, was found on some of the December cuttings before they were planted. Most of the December cuttings died before they rooted, while most of the March cuttings died after rooting. Both groups were badly rotted when lifted. Only with the November cuttings, which was not diseased, was survival approximately equal to rooting.

The differences in rooting and survival of cuttings made at different times of the year and the relation of these differences to auxin treatment can probably be partly explained as follows: 1.--Cuttings rooting under favorable conditions (those made in March and rooted in April and May) performed very well without auxin treatment. 2.--Cuttings made in December were diseased before rooting, and therefore showed no auxin effect. 3.--Healthy cuttings made in November showed a significant response to auxins, possibly because the fall cuttings were dormant and auxin assisted in breaking the dormancy, and perhaps because the auxin was more effective in stimulating rooting when the temperatures were below optimum. Unfortunately, the absence of good environmental control does not permit a conclusion on these points.

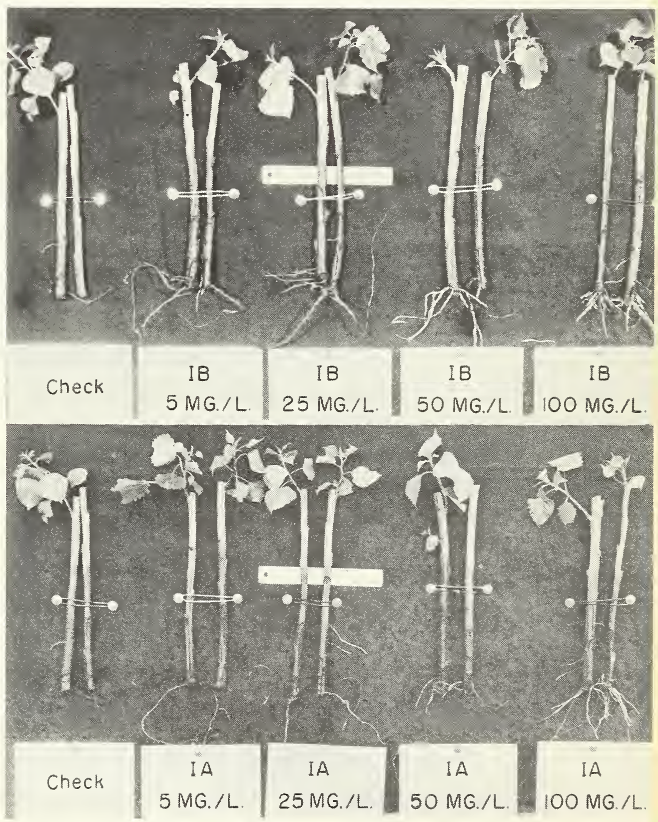

Figure 1.--November cuttings. Top: treated with indole-n-butyric acid. Bottom: treated with indoleacetic acid. (Ck=untreated.)

The effect of auxin on the number of roots per surviving cutting is not altogether clear. Generally, the auxin-treated cuttings produced more roots than untreated cuttings. The November cuttings treated with indole-n-butyric acid produced almost twice as many roots as those treated with indoleacetic acid (fig. 1). The roots on cuttings treated with indole-n-

butyric acid were larger in diameter, whiter, and more brittle than the more normal-appearing roots on cuttings treated with indoleacetic acid.

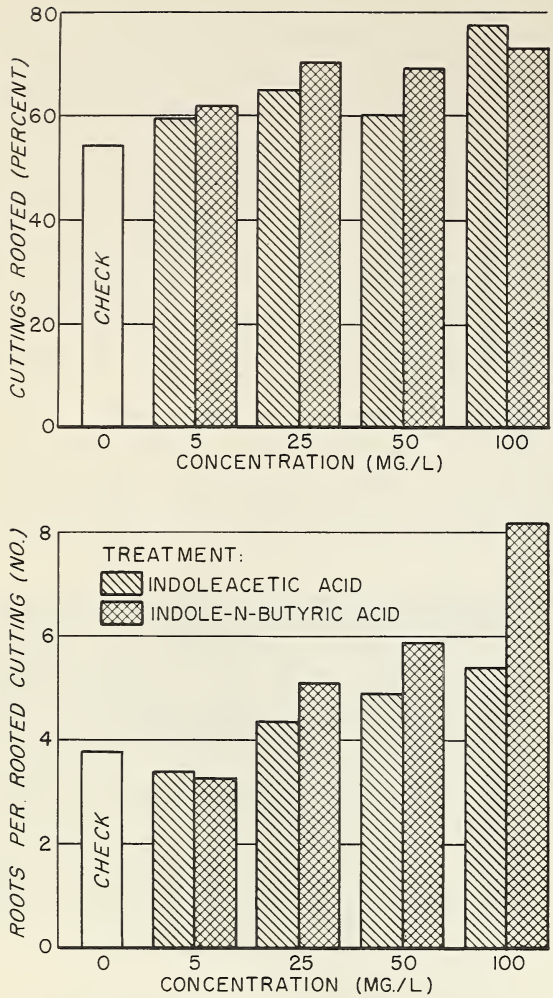

Figure 2. --Effect of auxin concentrations on cuttings.

Although auxin treatment increased the number of roots per cutting, it appeared to decrease top growth. The results, however, are not uniform and clearly defined. Seasonal factors, probably including both temperature and length of day, appeared to have a more important effect on shoot growth.

Increasing the auxin concentration tended to increase the percentage of rooted cuttings and the number of roots per cutting (fig. 2); top growth was either not affected or was slightly reduced.

SOIL-MOISTURE RELATIONSHIPS

The ability of cottonwood cuttings to root in the greenhouse under favorable conditions, and the frequent failures to root in field planting, suggest that field failures are due to unfavorable environment rather than to the inherent characteristics of the species.

Methods. --In the moisture experiment reported here, five soil-moisture conditions were used in each of two different soils, O'Neill sandy loam and Bremer loam. The O'Neill was a friable, well-aerated sandy loam. The Bremer was a more compact loam and not so well aerated.

The soils were collected in the field 24 hours after a saturating rain, when their moisture contents were assumed to be at the field capacity. Except in the first treatment described below, the soils were immediately placed in two-gallon crocks. Soil moisture at the time of potting was determined and this quantity designated as field capacity. The treatments were:

A. Below field capacity: The soil was allowed to dry until it contained 80 percent of the moisture designated as field capacity, and then it was mixed and potted. This moisture level was maintained by weighing the crocks daily and adding one and one-half times the amount of water lost below the designated level of 80 percent of field capacity.

B. Field capacity. The crocks were weighed daily and the moisture level maintained at the field capacity in the same manner as in Treatment A.

C. Capillary water. The crocks of soil were placed inside larger containers in such a manner that the drain holes in the bottoms of the crocks were just below the surface of the water in the outside container.

D. Saturated and drained. The crocks were placed inside larger containers that were filled with water. The water in the outside container was level with the surface of the soil. The water was allowed to rise through the drain hole of the inner crock and completely saturate the soil. Each morning the crocks were raised so that the drain hole was just below the water surface, and each evening they were submerged again. Thus the soil was alternately saturated and drained.

E. Saturated. The soil was held at saturation, in the manner described for D, for the period of the test.

This experiment was conducted in the greenhouse at temperatures between 65 and 75°F. Each of the five treatments was replicated four times in each soil, so that there was a total of 40 crocks. Seven cuttings were placed in each crock in January 1949, and these were lifted and measured 47 days later.

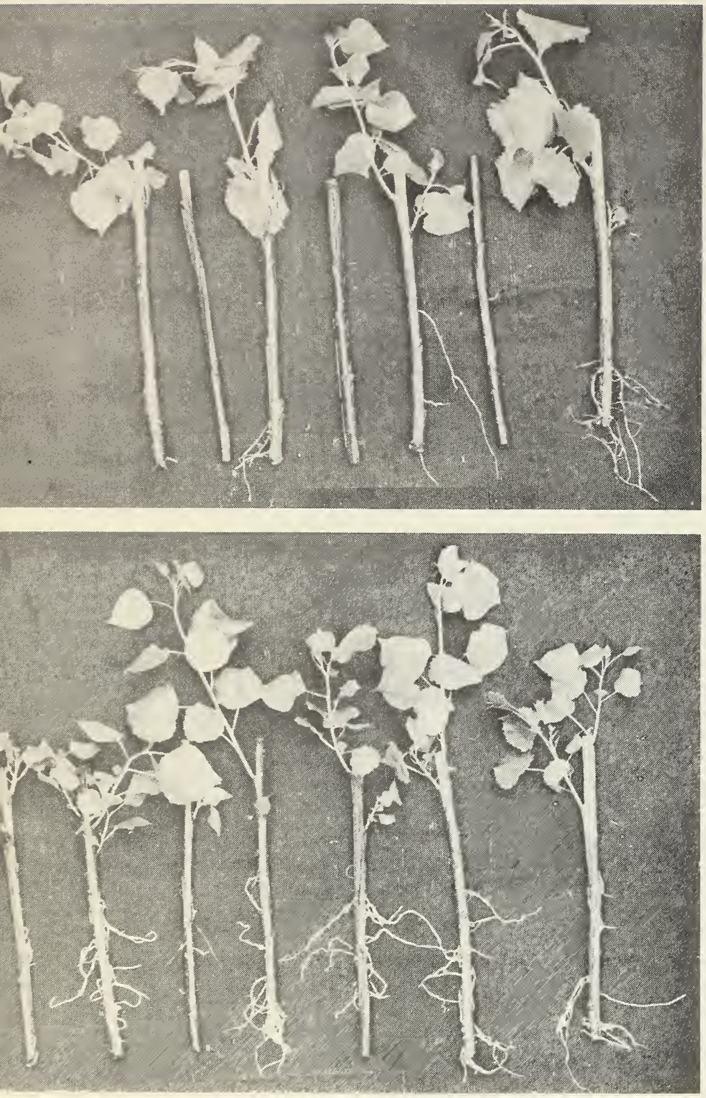

Figure 3.--Cuttings grown in Bremer soil. Top: in crocks supplied with capillary moisture. Bottom: in crocks with saturated soil.

Results and discussion.--Without some free water (water above the "field capacity"), rooting was not sufficient for good survival (fig. 3, table 4). Best survival was obtained in the continuously saturated soils. However, when the cuttings were lifted the leaves of those in saturated soil were beginning to yellow, and top growth was decreasing--the result of poor aeration.

Although the Bremer and O'Neill soils were quite different in their physical properties, they caused little variation in the response of the cuttings.

This experiment indicates that the reproduction of cottonwood by cuttings should be most successful on the low, moist sites which are the natural habitat

Table 4.--The effect of various soil moisture levels on the rooting of cottonwood cuttings

Soil moisture	Bremer soil		O'Neill soil	
	Survival	Roots per rooted cutting	Survival	Roots per rooted cutting
	Percent	Number	Percent	Number
Below field capacity	0	...	4	2
Field capacity	16	4	20	9
Capillary	67	15	64	19
Saturated and drained	62	21	61	20
Saturated	80	20	72	20
Mean	45	17	44	17

of this species. In contrast, reproduction by cuttings may be expected to be poor on upland sites, where this species is frequently planted for windbreaks. The use of the longer cuttings which penetrate into zones of higher soil moisture, and cultural treatments to improve soil moisture conditions in the planting area, should increase survival on the drier sites.

The high survival obtained with the "saturated" soil indicates that cottonwood will root successfully if environmental conditions are favorable. Where the environment is unfavorable, better rooting and survival may be obtained by auxin treatment. This, however, should be tested at different moisture and temperature levels. Studies of the dormancy of cottonwood shoots are also needed.

SUMMARY

Three separate lines of investigation were followed in studying the rooting of cottonwood cuttings.

The rooting ability of cottonwood cuttings decreased as the age of the cutting wood was increased from one to four years. Within the range tested, the diameter of the one-year-old cuttings did not affect the number of roots formed per cutting. Long cuttings rooted and survived better than short cuttings.

Treatment with indoleacetic acid or indole-n-butyric acid produced more rooted cuttings and more roots per cutting than appeared on the untreated controls. The number of roots per cutting increased as the concentration of indoleacetic acid or indole-n-butyric acid was increased from 5 to 100 milligrams per liter. Top growth, however, was less on treated cuttings than on untreated controls.

The higher the moisture level of the soil, the better was the survival and rooting of cuttings. Saturated soil gave the best results.

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